Article, Published Version

Wirth, Harry; Brüggemann, Thomas

Surveying of Extremely Shallow Waters with Optimized Multi-Beam Echo-Sounders and Survey Vessels

Hydrographische Nachrichten

Surveying of Extremely Shallow Waters with Optimized Multi-Beam Echo-Sounders and Survey Vessels

An article by *Harry Wirth* and *Thomas Brüggemann*

In 2008, the German Federal Institute of Hydrology (BfG) was commissioned to investigate possibilities of improving the efficiency of multi-beam echo-sounders for the use on inland waterways. The BfG identified parameters for the optimization of a combined multi-beam system that consisted of two Kongsberg EM 3002 echo-sounders, one equipped with a dual-head transducer and one with a single-head transducer. On most inland waterways this new system may increase the output of measurements by approximately 120 %.

multi-beam echo-sounder | shallow-water survey | triple-head MBES

1 System concept

The efficiency of hydrographic surveying systems using multi-beam echo-sounders may be increased by maximizing the area covered by the measuring signal (maximized transversal beam aperture) and by increasing the speed of the surveying vessel. However, to ensure the proper analysis and reliability of the measurement results, a minimum density of 5–10 measuring points per square metre must be provided. Moreover, overlapping with the neighbouring swathes should be minimized. The system has to be designed for maximum efficiency in waters deeper than 1.5 m.

The following concept is based on the assumption that the multi-beam echo-sounder forms the beams according to the »equal distance« principle.

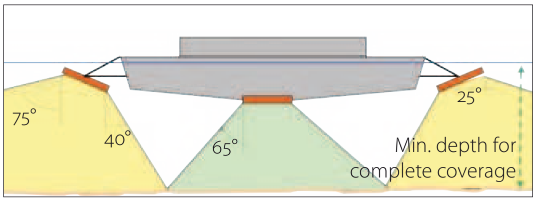

Fig. 1: Optimized transducer alignment with two combined multi-beam echo-sounders

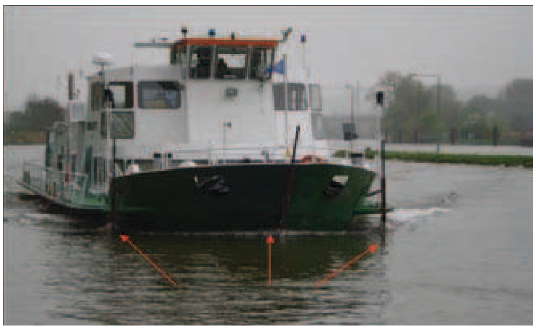

Fig. 2: Survey vessel PS »Johannes Kepler

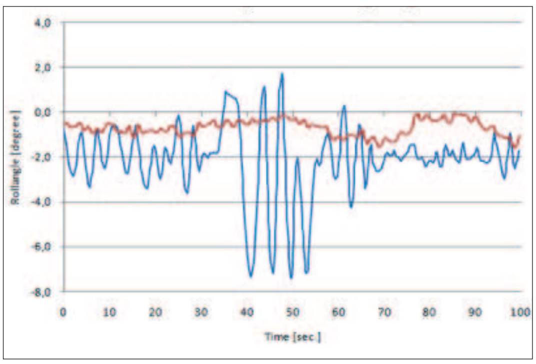

Fig. 3: Roll angles of the survey boats on a curved course; blue: »Reiher«, red: »Visurgis«.

1.1 Combined MBES with optimization of the transducer alignment

It is intended to maximize the swathe width by combining two multi-beam echo-sounders in such a way that full coverage of the area under the vessel is achieved. The outer transducers should be as little tilted against the horizontal as possible, so that the gap in coverage to fill below the vessel remains minimal. When the outer transducers are inclined by 25°, the outer beams with 75° tilt angle (measured against nadir) can be shifted to 90° for inspections of buildings or near-bank areas, i. e. the measurement can be made parallel to the water surface (see Fig. 1).

Provided the transducer heads are mounted at the vessel at a depth of 0.5 m, this alignment is suitable to close the gap in coverage below the ship's hull already at a water depth of 1.50 m by means of a third transducer, if the distance between the outer transducers is not more than 6 m. If they are 9 metres apart, the water depth must be more than 2.01 m.

To avoid deterioration of the accuracy of coordinates when transferring them to the transducer centres, excentricities between heave-roll-pitch sensors, positioning system and transducers must be kept at a minimum.

1.2 Optimizing swathe-width planning and the survey vessel type

To ensure the preservation of the minimum density of measuring points, the overlap of the swathes should be chosen so that influences of imprecise navigation along survey route (about ±2–3 m), the roll of the vessel and the variation of swath width caused by varying water depth are compensated.

If the swathes are oriented parallel to the depth layers, a swathe overlap of 5 m is sufficient in evenly sloped, structurally less diversified terrain. In practical application it is necessary to plan the survey routes on the basis of previous surveys. When the outer oscillators are tilted by 25°, roll movements of the vessel reduce the effective aperture angle of 2 × 75° (each referenced to the nadir). Accordingly it is essential for the survey vessel to keep stable in the water. The roll angles should be ≤ ±3°. Directional stability can be achieved with vessels of more than 20 m length.

2 Results of the field tests

The tests were made with the EM 3002 by Kongsberg on the survey vessel »Johannes Kepler« (see Fig. 2) of the Waterways and Shipping Directorate South (WSD Süd). The mounting was temporarily fixed to the vessel following the instructions given by the BfG.

Signal superposition between the transducers had to be suppressed or avoided by controlled triggering of the signals of the combined echo-sounder systems.

2.1 Survey vessel test

The shape and the size of the boat hull define the dynamical behaviour of the survey vessel, what can have considerable influence on its navigability and on the accuracy of measurements. To find the best compromise, the dynamic behaviour of a catamaran vessel (MS »Visurgis«) was tested and evaluated in comparison with standard vessels (like the MB »Reiher«) in dependence on manoeuvres, waves, wind, and cross currents (see Fig. 3).

Being a catamaran, the survey boat »Visurgis« shows only $^1/_5$th of the roll movements of the standard survey boats »Reiher« in monohull design. Thus, the »Visurgis« type meets the limits of ±3° required for the combined echo-sounder system without problems. The catamaran design also allows very exact navigation along the planned survey route.

2.2 Multi-beam investigation and improvement

The transversal standard mounting angle of the dual-head-(v-shaped) MBES used to be 40°. In order to eliminate or minimize the influence of total reflexions, the installation angles of the transducers were varied. The computed theoretical optimal value of 25° was verified in practical tests.

The field tests yielded an unacceptable number of severe errors in the measurements (see Fig. 4 a). We observed different categories of causes for the erroneous measurements:

- Errors due to multiple signal paths in areas with very firm subsoil (see Fig. 4 a, green measurements seemingly below the seafloor);
- Errors due to signal interferences between the main lobe and the side lobes (blue and red measurements seemingly above the seafloor);
- Errors due to strongly reflecting small and compact objects (e. g. rip-rap stones).

Therefore the bottom-detector algorithms of the EM 3002 had to be improved by Kongsberg.

After further development and modifications, the system was working with satisfactory reliability and accuracy (see Fig. 4 b).

However, the required triggering of the MBES reduced the frequency of soundings nearly to its half, i. e. to about 9 Hz. Because of the even distribution of measuring points with the equal-distance mode, the minimum density of points within one swathe could still be achieved at a speed over ground of 12–13 km/h (see Fig. 5).

The remaining critical marginal areas (red colour) are sufficiently filled by overlapping neighbour swathes.

3 Summary

The tests proved the general applicability of a combined multi-beam echo-sounder system on the basis of the EM 3002 by Kongsberg Maritime. In the field tests it was shown that surveys can be made at a cruising velocity of 12 km/h without putting the required data density at risk.

Moreover, it was shown that on inland waterways the combined system makes it possible to increase efficiency significantly by some 120 % against the conventional multi-beam echo-sounder systems. The alignment of the transducers suggested by the BfG proved to be practicable. Below a water depth of 2 m the combined echo-sounder system was more efficient than a multi-channel system with swinging booms (sweep sounder).

The requirements on data transfer and evaluation increase with a combined triple-head MBES insignificantly, if at all, against a dual-head system. □

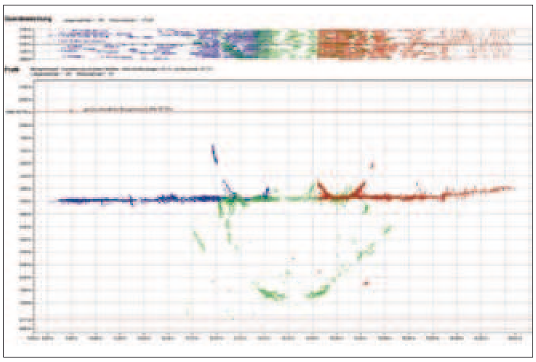

Fig. 4 a: Error performance of the system before the modification

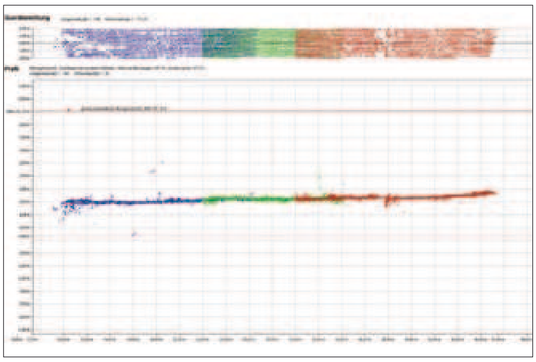

Fig. 4 b: Error performance of the system after the modification

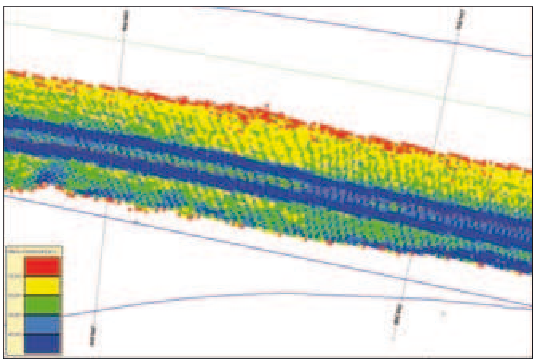

Fig. 5: Colour-coded data density in meshes (size 1 × 1 m), cruising velocity about 12–13 km/h, depth about 3 m, red signifies data density of less than 10 measurements/m²

Authors

Harry Wirth works at the German Federal Institute of Hydrology (BfG) as head of the team for hydrography.
Contact:
wirth@bafg.de

Thomas Brüggemann works at the German Federal Institute of Hydrology (BfG).
Contact:
brueggemann@bafg.de